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Aggregate Food Demand and the Supply of Agricultural Products

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ABSTRACT

Food demand may be somewhat more price inelastic than previously estimated. The simple four-equation model developed here provides a formal empirical framework linking food demand to supply. Medium-range forecasts indicate that food prices may continue to rise slightly faster than average prices for all items over the next 5 years. The model represents a middle-of-the-road approach to forecasting that may be more cost-effective than time-series or a multi-equation, multicommodity approach.

Keywords: Food demand, agricultural products supply, econometric model

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SUMMARY

Food demand may be somewhat more price inelastic than previously estimated, based on the results presented in this report. A simple four-equation model is used to provide a formal empirical framework linking food demand to supply. Statistical tests indicate that: 1) demand-pull from rising real incomes and cost-push from upward movements in prices paid by farmers play an important role in determining food and agricultural prices, consumption, and production; 2) it makes little difference whether expectations are formed rationally or are naive; 3) medium-range forecasts show food prices may continue to rise slightly faster than average prices for all items over the next 5 years.

The model presented in this report represents a middle-of-the-road methodology for forecasting between the extremes of pure time-series analysis and a multi-equation, multicommodity modeling approach. Given the absence of theoretical content in the former and the maintenance costs of the latter, simple aggregate models such as this may be most cost effective.

Aggregate Food Demand and the Supply of Agricultural Products

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INTRODUCTION

Since the publication of Girshick and Haavelmo's classic work on simultaneity in food demand and agricultural supply in 1947, most empirical studies of the food and agricultural sector have focused on disaggregated markets (9).[1/] Although studies of disaggregated market behavior yield useful conclusions, their aggregate implications are often unclear. One alternative framework for exploring aggregate behavior in the food and agricultural sector is a general model containing demand and supply subsystems, the linkages between these subsystems, and a set of aggregation relations.

Although attempts have been made in this direction, complete specifications are probably beyond the scope of most research studies. Even if a suitable model could be developed, it would be useful only for policy analysis and short-term forecasting; limited sample size would not allow forecasts 5 to 10 years into the future with any degree of statistical confidence. Hence, if there is both a major interest in the aggregate structure of the food and agricultural sector, as well as a desire for medium-range forecasts, aggregate sector models with sufficiently lengthy time series must be relied on. This necessarily implies a fairly simple structural representation.

This paper offers a straightforward specification of such a model. Its design goals are: (1) to provide a formal summary of the structure of the food and agricultural sector based on generally accepted theory, and (2) to generate medium-range forecasts of the principal sector aggregates.

BACKGROUND

Attempts to estimate aggregate demand equations for food date back to the twenties and thirties with much of the early work done by the U.S. Department of Agriculture (26). The basic theoretical framework was simply the static choice model--consumption was written as a linear function of price, income, and prices of related goods. In the forties, Girshick and Haavelmo utilized this demand representation with values deflated using the Consumer Price Index (CPI) as part of their five-equation, simultaneous model of the food and agricultural

1/ Underscored numbers in parentheses refer to items listed in the References section.

sector (9). Daly, Waugh, and a succession of other analysts utilized the same methodology during the fifties to perform partial equilibrium studies of aggregate food demand (7, 26). Brandow, Brown and Heien, George and King, and Hassan and Johnson estimated disaggregated food demand systems from which aggregate inferences could be drawn through summation, while Green, Hassan and Johnson, Phlips, and others estimated complete demand systems with food as one of several aggregate goods (3, 4, 6, 8, 11, 13, 18, 21). Recently, Mann and St. George estimated aggregate food demand functions in varying functional forms (17). The major parameters of interest in virtually all these studies were price and income elasticities of food demand.

Table 1 presents selected price and income elasticities of food demand from some of the empirical studies performed in the post-war period. A variety of data sets, functional forms, and approaches are represented. Even so, the limited range of the

Table 1--Price and income elasticities of demand for food from selected studies 1/

Analyst	Estimation period	Price elasticity	Income elasticity	Characteristics
Waugh	1927-41	-0.24	0.24	--
	1948-62	-.24	.14	--
Girshick-Haavelmo	1922-41	-.25	.24	Deflated
Daly	1929-56 (less 1942-47)	-.27	.52	Deflated
Brandow	1923-56 (less 1942-47)	-.35	.26	--
George-King	1946-68	-.24	--	System
Phlips	1929-70	-.20	--	System dynamic
Mann-St. George	1957-76	-.17 to -.33	.10 to .22	Various functional forms

-- = Not applicable.

1/ In all cases aggregate, single-equation static demand models, with values not deflated, were used unless otherwise noted.

reported price elasticities is striking--all lie within the bounds 0.17 to 0.35. Estimated income elasticities also are reported within a relatively narrow range of 0.10 to 0.26, with the exception of Daly's estimate of 0.52. The basic implication is that food demand is highly inelastic, and that food is a necessity. This result is intuitively reasonable and probably one of the few consensuses in empirical economics.

Aggregate supply has received somewhat less attention than aggregate demand. After Girshick and Haavelmo, Griliches' work in the fifties and that of Tweeten and Quance in the sixties are perhaps the best examples of attempts to estimate aggregate supply functions (9, 12, 24). Much effort focused on individual product supply response following Nerlove's approach (20). Rarely were there attempts to estimate complete supply systems to obtain aggregate elasticity estimates, even though the process would have been relatively simple. In general, a review of the literature suggests that there has been less interest in aggregate supply than demand, and less emphasis in the application of the systems approach in supply analysis than in the case of demand.2/

Much of the early work on the specification of supply functions, in both aggregated and disaggregated studies, presumed that past prices were basic determinants of production. For example, Girshick and Haavelmo estimated a supply equation with production dependent on current and lagged price. Nerlove argued that expectations were adaptive. He also estimated supply equations with both lagged production and prices included on the right-hand side. Griliches, Tweeten and Quance, and a generation of applied analysts relied heavily on Nerlove's specification under the theoretical rationale that desired production depends on expected prices, both for inputs and products. Estimates of aggregate supply elasticities from these studies, normally reported with respect to expected price, range from Griliches' estimate of 0.10, to 0.16 as reported by Tweeten and Quance. Others find similar levels, implying a nearly universal consensus that the supply of agricultural products is highly inelastic.

Many different approaches were used regarding the linkages between the food and agricultural product markets. In some studies, an aggregate derived demand equation for agricultural products was estimated with income included on the right-hand side. In others, an aggregate production function was used to

2/ One reason for this may be the absence of a well-developed literature on supply systems. Alan and Gruen (1) outlined a linear systems approach for supply analysis, but applications have been rare.

link agricultural output to food supply. In contrast, some analysts used market "spread" equations to relate agricultural product prices to those in the food market. For this reason, cross-study comparisons and generalizations about linkages between markets for food and agricultural products are difficult to make.

A basic approach for examining the relationship between product and resource markets is contained in static choice theory: utility maximization yields consumer demand functions; firm profit maximization generates product supply and resource-derived demand functions; profit maximization by firms in the resource market gives rise to resource supply equations; and the interaction of buyers and sellers leads to instantaneous equilibrium. Of course, this version of reality has been supplanted by complex behavioral representations generally accepted as more appropriate. Houthakker and Taylor and later Phlips assume that consumer decisions regarding stocks of goods reflect habit formation (15, 21). Under a proportionate depreciation rule, this leads to the inclusion of lagged consumption in demand equations. Similarly, in the case of agricultural products, the static supply function was dismissed in favor of Nerlove's dynamic specification, with production written as a function of expected prices and lagged production. This is thought to reflect more fully the choice dynamics of agricultural producers. Dynamic versions of product supply and input-derived demand specifications have also been proposed but not as widely accepted.

Given these considerations, it would seem appropriate to model aggregate food demand using the Houthakker-Taylor approach, aggregate food supply and the derived demand for agricultural products as static, and aggregate farm level supply as dynamic following Nerlove. Hence, under the assumption of approximate linearity, the result is a dynamic simultaneous equation model with recursive supply.

By including preselected time transforms as proxies for technology change, binary variables for war years, apparel as a substitute for food, and the ratio of prices paid to prices received by farmers in the supply equation, the resulting model specification is:

$$(1)\quad q_t = \theta_0 + \theta_1 p_t + \theta_2 m_t + \theta_3 a_t + \theta_4 q_{t-1}$$

$$\theta_1 < 0, \quad \theta_2, \theta_3, \theta_4 > 0$$

$$(2)\quad q_t = \phi_0 + \phi_1 p_t + \phi_2 r_t + \phi_3 \log t + \phi_4 w_t$$

$$\phi_1, \phi_3, \phi_4 > 0, \phi_2 < 0$$

$$(3)\ x_t = \beta_0 + \beta_1 p_t + \beta_2 r_t + \beta_3 \log t + \beta_4 w_t$$

$$\beta_1, \beta_3, \beta_4 > 0,\ \beta_2 < 0$$

$$(4)\ x_t = \sigma_0 + \sigma_1 x_{t-1} + \sigma_2\, E_{t-1}(r_t/v_t) + \sigma_3 t^2$$

$$\sigma_i > 0\ \forall\ i$$

where equation (1) represents the demand for food, (2) reflects the supply of food, (3) is the derived demand for agricultural products, and (4) is the supply of agricultural products; q_t is food consumption (endogenous); m_t is income; x_t is agricultural production (endogenous); w_t is a binary variable equal to unity in war years and zero otherwise; p_t (endogenous), r_t (endogenous), v_t, and a_t are the prices of food, agricultural products, agricultural inputs, and apparel, respectively; and $E_{t-1}(\ldots)$ denotes conditional expectation based on information available in t-1.[3/]

Clearly, the specification of the expectations formation process $E_{t-1}(r_t/v_t)$ determines the basic model structure. Early studies assumed simply that this year's expected ratio of prices received to prices paid equaled last year's actual ratio, that is, $E_{t-1}\ (r_t/v_t) = r_{t-1}/v_{t-1}$. This type of expectations formation process is normally described as "naive" expectations formation and is taken as a conjectural hypothesis. Nerlove rejected naive expectations as overly simplistic, proposing "adaptive" expectations where each expectation is generated by an autoregressive moving average process. Recently, more complex expectations formation processes have been hypothesized in which agents' expectations are generated conditionally on the basis of all information available during period t-1. Under these circumstances, expectations are said to be "rational." Because rational expectations are conceptually the most complex and contain adaptive expectations as a special case, rational and naive expectations are treated as the two polar cases of interest.

ESTIMATION

To construct a forecasting model capable of making medium-range forecasts with sufficient statistical confidence, a lengthy time series is required. Historical data on the variables included in the model are available from 1914 to 1980. Using

3/ The form of time transforms and the inclusion of war-year binary variables is a result of preliminary experimentation using a restricted data set. The use of apparel as a food substitute is due to data availability. Inclusion of the "prices received to prices paid" ratio in the agricultural product supply equation follows convention established in previous studies.

this data, three-stage least squares (3SLS) estimates of the model under both naive expectations formation and rational expectations are first obtained (table 2). The lagged ratio of prices received to prices paid by farmers is included to measure naive expectations. Rational expected prices are obtained by regressing the ratio of prices received to prices paid on all endogenous variables lagged 1 through 3 years and on the remaining variables in the agricultural supply equation, each lagged 1 through 3 years. Forecast values from this regression are then taken as rational price expectations. This approach, proposed initially by Sargent, is simpler than that advocated by Wallis and presumes that decision-makers can perform least squares forecasts consistently (23, 25). A comparison of the two sets of estimators indicates that the naive expectations version of the model differs only marginally from the rational expectations version. In both, virtually all estimated coefficients are highly significant statistically and of expected sign.[4/] Furthermore, tests of the hypothesis of parameter equivalence in each model are accepted in all cases. Hence, the available statistical evidence indicates that it is not important whether expectations are naive or rational--the results are much the same in either case. For this reason and for simplicity in application, the naive expectations model is used as a point of reference in the remaining discussion.

The actual derived reduced form and a linear approximation to the derived reduced form for the naive expectations version of the model are presented in table 3. The linear approximate reduced form is obtained by applying a Taylor series expansion to the agricultural product supply equation, and then deriving the reduced form. This is useful for simulation, forecasting, and as a means of obtaining the approximate dynamic multipliers

4/ The R^2 value for each system, calculated using the system vectors of endogenous values and errors, was found to be approximately .98. The residual variance-covariance correlation matrix was estimated as

$$\begin{bmatrix} 1.00 & 0.45 & 0.16 & 0.07 \\ & 1.00 & .58 & .12 \\ & & 1.00 & .17 \\ & & & 1.00 \end{bmatrix}.$$

Table 2--Three stage least squares estimates of the model[1/]

Equation	Estimate
Naive expectations:	
Demand	$q_t = \underset{(5.6)}{25.7} - \underset{(.040)}{.075}\, p_t + \underset{(.0007)}{.0034}\, m_t + \underset{(.020)}{.042}\, a_t + \underset{(.06)}{.69}\, q_{t-1}$
Supply	$q_t = \underset{(4.0)}{20.5} + \underset{(.09)}{.50}\, p_t - \underset{(.030)}{.074}\, r_t + \underset{(1.41)}{9.01} \log t + \underset{(1.4)}{4.9}\, w_t$
Derived demand	$x_t = \underset{(13)}{-187} + \underset{(.32)}{3.21}\, p_t - \underset{(.10)}{.82}\, r_t + \underset{(4.0)}{12.1} \log t + \underset{(5.1)}{24.5}\, w_t$
Farm supply	$x_t = \underset{(4.6)}{20.6} + \underset{(.11)}{.38}\, x_{t-1} + \underset{(2.1)}{4.4}\, (r_{t-1}/v_{t-1}) + \underset{(.0015)}{.0082}\, t^2$
Rational expectations:	
Demand	$q_t = \underset{(5.6)}{29.1} - \underset{(.044)}{.066}\, p_t + \underset{(.0007)}{.0035}\, m_t + \underset{(.021)}{.035}\, a_t + \underset{(.06)}{.65}\, q_{t-1}$
Supply	$q_t = \underset{(4.0)}{20.6} + \underset{(.10)}{.48}\, p_t - \underset{(.031)}{.070}\, r_t + \underset{(1.40)}{9.22} \log t + \underset{(1.5)}{4.8}\, w_t$
Derived demand	$x_t = \underset{(14)}{-190} + \underset{(.39)}{3.34}\, p_t - \underset{(.12)}{.84}\, r_t + \underset{(5.32)}{9.87} \log t + \underset{(5.7)}{25.5}\, w_t$
Farm supply	$x_t = \underset{(4.9)}{18.6} + \underset{(.11)}{.41}\, x_{t-1} + \underset{(2.3)}{5.0}\, E_{t-1}(r_t/v_t) + \underset{(.0015)}{.0080}\, t^2$

1/ Variable definitions: q = food consumption index; p and a = CPI's for food and apparel; r and v = prices received and paid by farmers; m = per capita disposable income in dollars; x = agricultural production index; and w = binary variable for war years. All values are deflated using the CPI; base year for all indexes is 1967; estimation period is 1914-1980.

Source: Agricultural Statistics and Handbook of Labor Statistics.

Table 3--Derived reduced forms for the naive expectations model

Endogenous variable	Estimate
Actual model:	
Price (p_t)	$- 45.3 + .012\ m_t + .15\ a_t - .0025\ t^2 - 28.0 \log t - 9.53\ w_t$
	$- 1.35\ (r_{t-1}/v_{t-1}) + 2.41\ q_{t-1} - .11\ x_{t-1}$
Consumption (q_t)	$29.1 + .0025\ m_t + .031\ a_t + .00019\ t^2 - 2.11 \log t + .72\ w_t$
	$+ .10\ (r_{t-1}/v_{t-1}) + .51\ q_{t-1} + .0087\ x_{t-1}$
Prices received (r_t)	$- 429.6 + .046\ m_t + .57\ a_t - .020\ t^2 - 94.7 \log t - 7.4\ w_t$
	$- 10.7\ (r_{t-1}/v_{t-1}) + 9.40\ q_{t-1} - .91\ x_{t-1}$
Production (x_t)	$20.6 + .0083\ t^2 + 4.45\ (r_{t-1}/v_{t-1}) + .38\ x_{t-1}$
Linear approximate:	
Price (p_t)	$- 46.9 + .012\ m_t + .15\ a_t - .0025\ t^2 - 28.1 \log t - 9.61\ w_t$
	$+ .019\ v_{t-1} + 2.42\ q_{t-1} - .017\ r_{t-1} - .12\ x_{t-1}$
Consumption (q_t)	$29.2 + .0025\ m_t + .031\ a_t + .00019\ t^2 - 2.12 \log t + .72\ w_t$
	$- .0015\ v_{t-1} + .51\ q_{t-1} + .0013\ r_{t-1} + .0087\ x_{t-1}$
Prices received (r_t)	$- 442.3 + .046\ m_t + .58\ a_t - .020\ t^2 - 95.0 \log t - 7.55\ w_t$
	$+ .15\ v_{t-1} + 9.46\ q_{t-1} - .13\ r_{t-1} - .91\ x_{t-1}$
Production (x_t)	$25.7 + .0083\ t^2 - -.063\ v_{t-1} + .056\ r_{t-1} + .38\ x_{t-1}$

for the system.[5] It indicates readily that the system is stable and converges cyclically over time to a steady state because all system modulae lie between zero and unity.

STRUCTURAL HOMOGENEITY AND PROPERTIES

The use of lengthy time series in this study is somewhat paradoxical, since the model structure is presumed stable throughout the estimation period. Traditionalists would clearly reject this notion of structural stability under the argument that consumer and producer decisions made in recent years bear little resemblance to those made 50 years ago.

Yet it can be argued that certain fundamental choices remain unchanged over time. The choice between food and apparel consumption is much the same today as it was decades ago, even though the composition of the food and apparel market baskets has changed. Similarly, there is no reason to presume that the relationship between income and food consumption has changed, and production decisions are as likely to depend on profitability now as they did many years ago. The composition of output and the bundle of resources used in production may have changed, but this does not preclude constancy in the relationship between real prices and the output level.

Fortunately, it is possible to test for structural stability explicitly. In this regard, three distinct hypotheses regarding model homogeneity are examined using the Chow test (5). The first test concerns whether the five war-year observations obey the same structure as the remainder of the sample. Given that the war-year observations need not be excluded, the second hypothesis concerns whether the additional 37 observations from 1944 to 1980 (the postwar and advanced technology era) obey the same structure as the 1914-43 sample (the prewar and depression era). Third, this sequence is reversed and a test is made to determine whether the 1914-43 subsample obeys the same structure as the 1944-80 subsample.

Table 4 presents F test statistics for each of these null hypotheses, both on an equation-by-equation basis and for the system as a whole. Individual equation tests are made using

5/ The model is, of course, linear in the parameters but not linear in the variables. Hence, to simulate or forecast, sequential solutions must be obtained through an iterative process where the lagged prices paid to received ratio is first computed and a new current prices paid index generated. This is then used to calculate a lagged prices paid to received ratio for the next period and the process is repeated. In contrast, lagged endogenous values feed back normally without additional operations in the linear approximate system.

the 3SLS vector of residuals for each equation, while the system test statistic is computed using the 3SLS vector of residuals for the entire system. The results indicate the hypothesis that war-year observations obey the same structure as the remainder of the sample can be accepted with considerable assurance. At the 95-percent confidence level, critical F(5,63) is 2.37, and critical F(20,211) is 1.57. Hence, there is little evidence indicating the war years should be excluded from any equation or the system.[6]

Table 4--Tests for model homogeneity

Equation	Complete sample versus: 1914-80 minus war years	1914-42	1943-80
Demand	F(5,62) = 0.92	F(37,25) = 1.11	F(30,32) = 1.43
Supply	F(5,63) = 1.71	F(37,25) = .49	F(30,32) = 1.67
Derived demand	F(5,63) = 1.18	F(37,25) = 5.97	F(30,32) = 11.53
Farm supply	F(5,63) = 1.51	F(37,26) = 1.95	F(30,33) = 1.21
System	F(20,211) = 1.40	F(148,101) = .72	F(120,129) = .79

Given the inclusion of war-year observations, the null hypothesis that the 1944-80 subsample obeys the same structure as the 1914-43 sample and its converse are tested. The second column of table 4 gives F test statistics of the null hypothesis that the 1944-80 observations obey the same relation as the 1914-43 sample, while the third column presents test statistics

6/ The Chow test is not as powerful as the conventional F test of equational equivalence. However, it is the only alternative available in situations where the number of observations is less than the number of parameters to be estimated. It was determined in subsequent tests that the intercepts for the food supply and derived demand equations differed during the war years. Hence, war-year binary variables were added to these equations.

for the null hypothesis that the 1914-43 observations obey the same structure as the 1944-80 sample. Since critical F(37,25) is 1.88 and F(30,32) is 1.82 at the 95-percent confidence level, there is substantial evidence indicating that the derived demand equation is not structurally homogeneous over the complete sample. However, because $F(\infty,\infty) = 1$, the available evidence suggests that the system is structurally homogeneous. Hence, system homogeneity is accepted, but some question persists concerning the derived demand equation.

Given system homogeneity, the structural estimates of the model become important. Table 5 presents deflated price, income, and apparel cross-price demand elasticities, as well as the elasticity of supply, all reported at mean sample levels by decade. Both the estimated price and income elasticities are substantially lower than those reported in other studies. The price elasticity at the mean sample level is -0.078, substantially below the -0.17 to -0.35 range reported by other analysts, while the income elasticity is 0.067, also lower than the 0.10 to 0.26 range previously reported. The mean cross-price elasticity of apparel at 0.046 and the supply elasticity at 0.52 are generally consistent with previous findings, indicating a lack of substitutes for food and an inelastic supply, but the real farm-level supply elasticity at 0.071 is somewhat lower than reported in previous studies. Each set of estimates also exhibits relative stability over time, except for the income elasticity, which more than doubles over the sample period, and the farm-level supply elasticity, which declines.

Table 5--Selected structural elasticities, 10-year and total sample means

10-year period	Elasticity				
	Price	Income	Apparel cross-price	Supply	Farm level supply
1920-29	-0.079	0.045	0.051	0.53	0.103
1930-39	-.073	.031	.047	.49	.096
1940-49	-.075	.045	.048	.45	.099
1950-59	-.079	.070	.045	.53	.064
1960-69	-.076	.087	.043	.51	.045
1970-79	-.076	.105	.037	.51	.045
Total sample	-.078	.067	.046	.52	.071

Of course, under simultaneity, food demand and supply elasticities do not really exist because price and quantity are not related causally. More revelant are the Goldberger dynamic multipliers embodied in the structure (10). Table 6 presents impact, 5 years of interim, and total multipliers for $1 increases in real income, and unit increases in the deflated CPI for apparel and the prices paid index. A $1 increase in real per capita disposable income leads immediately to a 0.012-unit increase in the food CPI, a 0.046 unit rise in the prices received index, and a small upward movement in consumption. After 1 year, the effects continue but are reduced in magnitude; the food CPI rises 0.005 units and the prices received index moves up 0.019 units. The effects subsequently decline until they are negligible after 5 years. After many years, a $1 increase in real income pushes up the food CPI by 0.023 units and the index of prices received by farmers by 0.083 units. At the mean sample level, this implies a 1-percent increase in income causes a 0.45-percent increase in the food CPI and a 1.35-percent increase in prices received.

Table 6--Selected approximate dynamic multipliers

Endogenous variable	Multiplier						
	0	1	2	3	4	5	Total
	1967 dollars						
Income (m_t):							
Price (p_t)	0.012	0.005	0.003	0.001	0.001	0.000	0.023
Consumption (q_t)	.003	.001	.001	.000	.000	.000	.005
Production (x_t)	.000	.002	.002	.001	.001	.000	.006
Prices received (r_t)	.046	.019	.009	.004	.002	.001	.083
	1967=100						
Price of apparel(a_t)							
Price (p_t)	.150	.068	.034	.018	.009	.005	.289
Consumption (q_t)	.031	.017	.009	.005	.002	.001	.067
Production (x_t)	.000	.026	.020	.013	.007	.004	.075
Prices received (r_t)	.579	.232	.107	.054	.028	.015	1.033
Prices paid (v_{t-1}):							
Price (p_t)	.017	.002	-.001	-.001	-.001	.000	.015
Consumption (q_t)	-.001	-.001	-.001	.000	.000	.000	-.004
Production (x_t)	-.055	-.015	-.005	-.002	.000	.000	-.078
Prices received (r_t)	.131	.024	.002	-.002	-.002	-.001	.151

The "demand pull" effect from rising income also characterizes apparel price increases. A one-unit increase in the apparel CPI has an immediate impact on food prices and prices received by farmers, but these effects decline substantially in subsequent years. The total effect of a 1-percent increase in the CPI for apparel is a 0.30-percent increase in the food CPI and a 0.89-percent increase in the index of prices received by farmers at the mean sample level. In actuality, real apparel prices declined over the sample period, while real income almost tripled. For this reason, the dominant demand-side factor influencing behavior in the food and agricultural sector has been rising real income.

Upward movements in real prices paid by farmers are found to have virtually all of their impact on food prices and prices received by farmers after a 1 year interim. At the mean sample level, a 1-percent increase in prices paid by farmers ultimately causes a 0.015-percent increase in food prices and a 0.18-percent increase in prices received by farmers. For this reason, "cost push" at the farm level ultimately has only a limited impact at retail, but a moderate effect on farm level prices. In addition, indications are that higher prices paid by farmers cause declines in production and consumption, with most of the response coming the following year.

FORECASTS

The normal procedure for validating forecasting models is to test their predictive ability over a sample period beyond that used in estimation. The costs of preserving data for model validation are sometimes substantial, however; the use of additional sample information may affect parameter estimates significantly. For this reason, all available data is used in model specification and estimation in this study. The benefit is a narrowing of confidence intervals about forecasts, while the cost is an increase in uncertainty from an absence of information on previous predictive performance.

To actually make forecasts, the processes determining the current exogenous variables must be specified. This is not difficult compared with specifying the structure generating the endogenous variables because the variances of the exogenous variables are much smaller than those of the endogenous variables. Hence, each exogenous variable to be forecast (real income, the CPI for apparel, and the index of prices paid by farmers) is assumed generated by a third order autoregressive process with linear and quadratic time trends. These simple representations are found to explain over 90 percent of the movement in the CPI for apparel and the index of prices paid by farmers, and 99 percent of the variation in real disposable income.

Table 7 shows actual percentage changes in model variables from from 1976 to 1980, and forecast changes from 1981 to 1985. Indications are that (1) real food prices will continue to move upward following a downturn in 1982; (2) food consumption will grow moderately but slow from recent trend; (3) agricultural production will continue to increase along long-term trend; and (4) real prices received by farmers will decline substantially in 1981 and 1982, with a moderate recovery in 1984 and 1985. The upward movement in food prices is obviously a consequence of demand-pull from real income increases, while increases in prices paid have a dampening effect on prices received.[7/]

Combining the food price forecasts (table 7) with "consensus" forecasts of CPI changes yields nominal food CPI predictions (table 8).[8/] The scenario is clearly one where, under the stated assumptions, the CPI for food will continue to rise at a rate slightly exceeding the change in the CPI for all items. This represents a continuation of the pattern exhibited in the seventies when food prices increased more rapidly than the CPI.

CONCLUSIONS

The simple aggregate model presented here provides a formal empirical framework linking the demand for food to the supply of agricultural products. There have been only limited attempts in this direction over recent years, with most empirical efforts focusing on demand systems or disaggregated supply response. The results indicate: (1) the demand for food may be more price inelastic than previously thought; (2) it makes little difference whether expectations are formed rationally or are naive; and (3) both demand-side and supply-side variables play an important role in determining food and agricultural prices, consumption, and production.

Nelson has shown that models need not be complex to be good forecasting tools (19). The present study illustrates that models need not be complex to have interesting and useful structural implications. Using simple aggregate models also represents a middle-of-the-road approach to forecasting between the extremes of pure time-series analysis and the multi-equation, multi-commodity systems approach. Given the maintenance

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7/ The presented forecasts should not be taken as official Department forecasts, but are simply one set of prospective forecasts generated mechanically using the modeling approach outlined in this paper.

8/ Consensus CPI forecasts are obtained from the U.S. Department of Agriculture 5-year "baseline."

Table 7--Recent history and forecast percentage changes in endogenous variables, 1976-85

Year	Exogenous variable			Endogenous variable			
	Income (m_t)	Prices paid (v_t)	Apparel (a_t)	Price (p_t)	Consumption (q_t)	Production (x_t)	Prices received (r_t)
				Percent			
Actual:							
1976	2.2	0.8	-1.9	-2.2	3.8	2.6	-5.2
1977	2.3	-1.2	-1.8	-.1	-.9	1.7	-7.4
1978	2.7	.7	-4.0	2.1	-.9	2.5	5.9
1979	0	2.7	-6.2	-.3	1.9	5.7	3.7
1980	-3.3	-1.0	-5.6	-4.4	0	-4.7	-10.6
Forecast:							
1981	.6	-1.1	-1.1	.9	-.6	2.2	-9.3
1982	2.3	-.5	4.5	-1.3	.1	1.6	-7.8
1983	3.1	.0	3.4	1.0	.4	1.5	1.9
1984	3.3	.2	.0	1.4	.6	1.7	4.0
1985	3.1	.4	-2.1	1.4	.6	2.8	3.5

costs of the latter and the absence of theoretical content in the former, simple aggregate models may represent a cost-effective forecasting approach largely neglected recently.

Table 8--Forecast changes and levels in the Consumer Price Index for all items and food

Year	CPI for all items		CPI for food	
	Change	Level (index)	Change	Level (index)
	Percent	1967=100	Percent	1967=100
1980 (actual)	13.5	247	8.6	255
1981	10.5	273	11.4	287
1982	8.8	297	6.5	304
1983	9.0	324	10.0	334
1984	7.4	348	8.8	362
1985	6.6	371	8.0	393

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